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Do R&D Subsidies Matter? – Evidence for the German Service Sector

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ZEW

Zentrum für Europäische
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Centre for European
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Non-technical summary

In recent years the service sector is often called the driving force of industrialised economies. Innovative services promise advantages in international competition. Today, many R&D activities are carried out in the service sector. On one hand, this is due to outsourcing strategies of manufacturing firms in the eighties. On the other hand the dissemination of information and communication technologies provides many opportunities for innovative services, which are today known as the new economy.

Since the eighties Federal Government promotes R&D activities in the service sector to strenghten Germany's technological performance. Some examples of subsidised R&D activities in services are solutions such as tools for business software, control systems for traffic like railways or processes to develop high-performing solar cells for ecologically desirable energy. Moreover, engineers' knowledge is essential to dismantle nuclear power plants. Another case of promoted R&D undertakes the subsidiary for technical services of the Lufthansa AG. It is inspecting airplane materials using and developing high-tech detectors.

The focus of our paper is to analyse the innovative activities of subsidised German service firms. We investigate whether firms that receive public funding for innovation projects engage more in innovative activities than others. Additionally, we test the hypothesis that innovative firms are more likely to receive public grants in the future.

We use 2,451 observations on German service firms from the years 1994 to 1998 to investigate both research topics using OLS and Tobit regression methods. Empirically, it turns out that public grants raise the firms‘ privately financed innovative activities. The more grants a firm has received in the past, the more it invests in current innovation projects. Furthermore, innovating firms are more likely to have future access to public grants. Additionally, the share of university graduates of firms' total employees is an important factor for future participation in public R&D schemes.

Do R&D Subsidies Matter? –
Evidence for the German Service Sector

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March 2001

Abstract

In recent times the service sector is often called the driving force of today's economies. This paper analyses the innovative activities of German service firms. We investigate whether firms that receive public subsidies for innovation projects engage more in innovative activities than others. Additionally, we test the hypothesis that innovative firms are more likely to get public grants in the future. Empirically, it turns out that public grants raise the firms' privately financed innovative activities. The more grants a firm has received in the past, the more it invests in current innovation projects. Furthermore, innovating firms are more likely to have future access to public grants. Additionally, the share of university graduates of firms' total employees is an important factor for future participation in public R&D schemes.

Keywords: Innovation, Public R&D Subsidies, Service Sector, Policy Evaluation
JEL-Classification: O31, H32, C20, C24

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1 Introduction

In 1999 Germany‘s total expenditure on research and development (R&D) was almost € 47 billion. About 66 % of this amount has been invested by industry, 16 % by the Länder and 18 % by the Federal Government. An international comparison of the publicly sponsored share of R&D shows that Germany is one of the leading countries in funding its technological performance. The main part of the Federal Government's and the Länders' money is invested in universities, public owned research facilities and non-profit institutions. However, 5 % (€ 2.2 billion) of German government's total R&D expenditure was spent on fostering the local industry. With this considerable amount the Federal Government intends to promote investments that yield innovations to strengthen Germany's competetiveness in the world‘s technology race.

The economic rationale for government involvement in the area of innovation is the existence of market failures associated with R&D. The diffusion of knowledge by R&D activities induces that the social rate of return is larger than the private one. Moreover, high risk for research implies high hurdle rates for companies to engage in such activities. According to Arrow (1962) the amount invested by firms in R&D is likely to be below the social optimal level. For that reason governments regard themselves as necessary players in research activities by enforcing positive externalities with different policy tools. Nevertheless, this rationale often raises some doubts.

Given any country's willingness to pay for business-related R&D the question arises, whether R&D policy really stimulates private R&D activities. It may be that government spending crowds out private money, because firms just substitute public money for their own. In this case the government supports projects that would have been implemented anyway (cf. Wallsten, 2000; Guellec and van Pottelsberghe, 2000).

For years, scientists have investigated the relationship between public and private R&D-investments. With different methodologies, such as case-studies, macro- and microeconomic analysis they try to yield substantive policy implications. In fact, Wallsten (2000) finds evidence, that US-grants crowd out firm-financed R&D spending, whereas Busom's (2000) analysis of Spanish firms and Lach's (2000) examination of Israel's industry find hints that public funding induces private effort. All studies exclusively focus on the manufacturing sector, which has to be seen as a shortcoming in recent times. This is understandable since for a long time the manufacturing industry has played the most important role concerning R&D, and so does economic research. However, times have changed and the service sector is catching up. Expectations of start-ups of the new economy like software companies or biotech firms confirm this trend. Although this development and its impact are widely discussed, no empirical study pays attention to R&D funding and companies related to the service sector. Hence, the question arises, which identified effects in international evaluations concerning public funded R&D activities are in line with service firms? This paper addresses the question of how service sector oriented R&D spending affects private innovation expenditure.

In order to answer this question, first the Federal Government’s most important R&D scheme and the development of funds for the service sector is described. Afterwards a brief literature review is given to introduce the empirical field of public and private R&D investments. In this review we focus on empirical evidence on the firm level. It summarises the current international status quo, mostly with respect to the USA. Coming up with hypotheses and differences for Germany, the data used in the present study will be explained. The relation between public and private R&D spendings in Germany is tested for the period of 1994 to 1998. The final part will discuss the results from regression analyses.

2 R&D funding in the service sector

In all industrialized countries we observe a shift of value added and employment from manufacturing industry to services. Since 1980, more than 50 % of gross value added is contributed by the service sector. As shown by the OECD (1996), employment in business services has more than tripled from 1970 to 1995, corresponding today to around 5-10 % of total employment. Moreover in the last years almost 80 % of all new ventures were companies in services. In industrialized countries the development of the service sector is most dynamic and often called the driving force of today‘s economies.

A brief overview on German R&D policy tools shows that 40 % of all Federal Government R&D expenditure (€ 3.5 billion) is spent in the form of "R&D project funding". Direct project subsidies are provided to firms, universities and other research facilities. Applicants have to apply for particular technological projects in programmes that are seen to be in the public interest. These programmes are usually initiated to overcome capital market failures and to secure Germany‘s technological competitiveness. Because direct funding is an incentive policy tool, it is designed as a cost-sharing arrangement. In particular, the Federal Government only pays a maximum of one half of the total costs of highly risk R&D projects.

In 1999 the direct project funding of civilian R&D was about € 2.0 billion. About € 0.54 billion was used by the Federal Ministry for Research and Education (BMBF) to promote the business enterprise sector (cf. BMBF, 2000). More than a quarter of all of these grants was used for R&D projects related to services. Over time the share of the total R&D business sector budget which was spent for service projects climbed from eight percent in 1982 to 23.5 % in 1997.

There are several companies in the service sector, which offer different kinds of solutions such as tools for business software, control systems for traffic like railways or processes to develop high-performing solar cells for ecologically desirable energy. Another example is consulting engineers' research in optimizing district heating facilities by online technologies. Moreover engineers' knowledge is essential to dismantle nuclear power plants. Finally, the subsidiary for technical services of the German Lufthansa AG is inspecting airplane materials, using and developing high-tech detectors.

3 Review of the Literature

After the US R&D budget was signifcantly raised during the 1950s Blank and Stigler (1957) were among the first to question the relationship between publicly funded and private R&D. With a large sample of firms they tried to test for a complementary or substitutive relationship between public and private R&D investment. The implications of such studies are still significant for today’s R&D politics because a complementary relationship legitimizes public fundings whereas substitution is almost regarded as misallocation.

Over the time and along with improved scientific methods it became clear that definite statements regarding the effect of public R&D funding cannot be made. Meanwhile, two main fields of research can be identified which are used to analyse the relationship between public and private R&D investment: qualitative and quantitative research studies. Qualitative data is frequently based on interviews or case-studies within a selected number of firms, whereas quantitative studies count for macro- and microeconomic information on a broad number of companies. David et al. (2000) surveyed macro- and microeconomic studies, focusing on their „net impacts“. Only two out of fourteen of these empirical studies indicated substitutive effects on the aggregate level. On the firm-level the results are less clear, i.e. nine out of nineteen find substitutional effects. In summary, macroeconomic studies usually identify a complementary and „good-natured“ relationship between public and private R&D expenditure, whereas micro-studies on the firm-level are not able to confirm this effect.

In contrast to studies which take national economies into account, the advantage of a microeconomic analysis is that it controls for detailed influences among several determinants that may have an impact on private R&D activities. Recent microeconometric studies approach the above question with firm level or business data provided by ministerial offices, business publishers, statistical offices or written surveys. On this data the impact of the available determinants on private R&D activities is tested by panel or cross-section econometric analysis (cf. Klette et al., 2000).

Beside the advantages of micro firm-level analyses, these studies require important assumptions and know-how. Lichtenberg (1984, 1987) mentions "serious reservations about interpretations" in former studies because of misspecifications. According to his explanation the significant differences in results of many studies derive from the fact that only different and unspecific data about private R&D activities is available. Moreover, an imbalance favoring larger firms as well as substantial errors within the functional relationship between public and private R&D expenditure can be observed.

In the nineties Busom (2000) und Wallsten (2000) address other serious problems: endogeneity and causality. The former, which is also described by Lichtenberg (1987) and Klette/Møen (1997), is linked to the public funding decision. The difficulty of this aspect lies within potential selection bias of the public institution that – depending on the applying firm and the relevant R&D project – is the only decider in the public funding process: “This makes public funding an endogeneous variable, and its inclusion in a linear regression will cause inconsistent estimates if it happens to be correlated with the error term“ (Busom, 2000: 114). Furthermore, the public institution might support only those firms and R&D projects that are expected to generate extensive economic spillover effects. The recipient firm would most likely not have increased its investment in these basic knowledge R&D projects (Busom, 2000: 114).

In order to separate these two processes, it is no longer sufficient to take only supported firms into account. Using a control group of firms that have not received public funding the real effects of public subsidies should be analysed. Busom (2000) explores this problem by applying a selection model. While Busom applies a participation dummy for the R&D activity, Lach (2000) is able to test the impact of the R&D program on the amount of investment with or without public support.

In line with many studies, we test the effects of public R&D subsidies on private R&D investment. Especially for the growing service sector, there is no evidence for social justification of government spendings. While other authors consider endogeneity of subsidies or simultaneity among innovation activities and public fundings, we address a new topic: We analyse whether public research fundings sustainably enforce innovative activities. Policy makers try to generate a long-lasting effect by funding private R&D activities. Usually, receipt of public R&D grants obligates to exploit the results of the funded research. For two years after completion of publicly funded projects, recipients hold the exclusive right to transfer the know-how into innovations. If firms do not utilise their efforts within a reasonable period of time, the whole knowledge collected becomes a public good. This governmental regulation may induce also higher innovation expenditure after participation in public R&D schemes. However, this question was largely ignored in the literature until today and empirical evidence is not available. Moreover, future access to public R&D programmes has not been investigated yet. Firms' innovation activities today may influence their chance of being successful in entering tomorrow's public R&D schemes. Our study focuses on these two issues using data on the German service sector between 1994 and 1998.

4 Empirical Study

4.1 Data

This study combines data of companies supported by the BMBF and data of the so-called "Mannheim Innovation Panel – Services" collected by the Centre of European Economic Research (ZEW).

The BMBF database contains information on "direct project support", generally known as mission-orientated R&D. This funding remains the most important and extensive instrument to foster R&D in Germany. Out of the total governmental R&D budget € 0.54 billion is granted to firms annually to conduct R&D without repayment (cf. BMBF, 2000). The BMBF database is a census of all funding granted to the business sector. Thus, all firms not included in the database did not receive public mission-orientated R&D from the BMBF. This information enables us to calculate the amount of this funding per firm for every year. We use information on the years 1989 to 2000 from this database. This enables us to calculate lags and leads of public R&D funding on the firm level.

The "Mannheim Innovation Panel – Services" (MIP-S) is conducted by the ZEW on behalf of the BMBF. The survey in the service sector was launched in 1995 and collects information on about 2,500 service firms annually. In 1997 it represented the German part of the second Community Innovation Survey (CIS2) of the European Commission (see Ebling et al., 1999, for a detailed description). The MIP-S contains data from the years 1994 to 1998.

The MIP-S includes the service sectors as printed in Table 4 in the appendix. However, not every sector on the three digit level contains firms which received public funding in the analysed time period. Thus, we restrict our analyses only to those three digit sectors that contain publicly supported firms (see Table 5 in the appendix).

The merging of both data sets leads to a sample of 2,451 observations used in this study. The sample contains 137 observations with a positive value of public R&D grants.

Using the MIP-S solves Lichtenberg's (1984) criticism that many studies only deal with large firms. The MIP-S includes firms with at least five employees and more. Our sample median of employees is 42 for non-supported firms and 103 for the subsidised ones.

4.2 Empirical Considerations

Our main question is whether the innovation activities of service firms are stimulated by public funding. Moreover, we analyse the relationship between innovation activities and future access to public research funding.

The innovative activity is measured as the expenditure on innovation projects at the firm level. The definition of innovation expenditures in the MIP-S is in line with the so-called OSLO-Manual (cf. OECD and Eurostat, 1997).

"In order to facilitate comparison with R&D expenditure it is recommended that information should be collected on the breakdown by technological product and process (TPP) innovation activity for total TPP innovation expenditure (current and capital expenditure). The following breakdown is recommended:

- R&D expenditure;
- expenditure for the acquisition of disembodied technology and know-how;
- expenditure for the acquisition of embodied technology;
- expenditure for tooling up, industrial engineering, industrial design and production start-up, including other expenditure for pilot plants and prototypes not already included in R&D;
- expenditure for training linked to TPP innovation activities;
- marketing for technologically new or improved products." (OECD/Eurostat, 1997: 87).

As we use this European standard definition of innovation expenditure, we ensure comparability to other European investigations and meet Lichtenberg's (1987) suggestion to use coherent data on innovation.

We consider the innovation intensity (*InnoInt*) as the dependent variable in the regressions, i.e. the innovation expenditure (*InnoEx*) are divided by sales:[2]

$$InnoInt_t = \frac{InnoEx_t}{Sales_t} \times 100 . \qquad (1)$$

The public R&D funding intensity in period t is measured as a lagged average of the recent 5 years' public fundings (*PF*) with respect to firm size measured by sales:

$$PFInt_t = \frac{\frac{1}{5}\sum_{i=1}^{5} PF_{t-i}}{Sales_t} \times 100 . \qquad (2)$$

It is often argued that R&D-processes are linked to a desirability of continuity and stability of research departments. In this context current innovation activities might be influenced by

[2] In the following we always omit the index i for the i-th firm. All measures are at the firm level, unless indicated otherwise.

different R&D projects. Using formula (2), we capture different programme durations. On average German public research funding lasts three years. Using a five year measure ensures that most research projects are completed. Like the innovation expenditure, the average amount of funding is related to firm size, i.e. sales. This lagged funding intensity is constructed to avoid direct simultaneity between firms‘ innovation intensity and public fundings. However, if a firm receives public fundings in period *t*, simultaneity may still occur. Thus, one can also calculate the „net innovation intensity“ for the period t

$$NetInnoInt_t = \left(\frac{InnoExt_t - PF_t}{Sales_t} \right). \tag{3}$$

This variable can be interpreted as the firms‘ privately funded innovation efforts in period t. The analysis of the dependence among *InnoInt* or rather *NetInnoInt* and *PFInt* is the first core question of our study. These analyses give an idea of the impact of former public research subsidies on today’s innovation activities. A positive correlation indicates that former public research subsidies have a lasting effect on private innovation activities.

To analyse the second question, whether innovative activities have an impact on future access to public innovation programmes, we construct a lead of a two-period average funding intensity (*LPFInt*) for the period t:

$$LPFInt_t = \frac{\frac{1}{2}\sum_{i=1}^{2} PF_{t+i}}{Sales_t} \times 100\,. \tag{4}$$

This approach provides information on the results of the competition on public fundings and reveals policy decisions.

We add several control variables to our regressions: Size effects are captured by the number of employees divided by one thousand (*EMP*) and its squared value (*EMP*^{2}). To distinguish the old and new states in Germany, we use a dummy variable *EAST* which indicates if a firm is located in Eastern Germany. Five industry dummies adjust cross-sectional effects (see Table 5 for further information) and four time dummies shift inter-temporal differences. Moreover, we add the firms‘ age to the regression equations. On one hand, a start-up implies one or more innovations (cf. Storey and Tether, 1996 or Hunsdiek, 1987). On the other, well established firms are possibly reluctant to fundamental innovations and thus invest less for innovative projects. We use an inverse relationship (1/*AGE*) because some firms are quite old and a linear specification may not fit for the young firms, which are expected to be more enthusiastic regarding innovations.

Additionally, we control for competition: The export ratio with respect to sales (*EXPORT*) measures the degree of international competition which the firm already takes on itself. Unfortunately, there are no standard variables like imports or industry concentration indices available from official statistics for the German service sector. Hence, we use a different measure for national competition: We add the growth rate of firms foundations on the NACE[3] three digit industry level (NC3)

$$GRFF_{t,NC3} = \frac{FF_{t,NC3} - FF_{t-1,NC3}}{FF_{t-1,NC3}} \tag{5}$$

This variable is taken from the „Mannheim Foundation Panels“ of the ZEW. *GRFF* marks the sectoral dynamics of the national economy and, thus, indicates the degree of competition. Note, that *GRFF* is also differentiated by East and West Germany. This takes account of the special situation of the transition economy of the new states.

Nelson hypothesized that only diversified firms will find it profitable to engage in R&D since they are better able to market invention results (cf. Nelson, 1959: 302, Link, 1982: 343). We take this hypothesis into account by creating a diversification index which is defined by the share of sales across the four different client groups j: 1) manufacturing sector, 2) service sector, 3) government and 4) private households:

$$DIV_t = \sum_{j=1}^{4} \left(\frac{Sales_t \ withclient \ j}{Sales_t} \right)^2 . \tag{6}$$

This client Herfindahl index equals one if a firm specialises on one group of clients, e.g. the firm only deals with firms of the manufacturing sector. If the firm shares a quarter of its sales with every group of customers, *DIV* takes the lowest value, i.e. 0.25.

The second model on the relationship between the future access to public research programmes and innovations contains a legal form dummy variable *LFD* which takes the value one for joint-stock companies or firms with limited liability; *LFD* = 0 otherwise. These legal forms indicate more reliable receipt of public funds. Joint-stock companies and firms with limited liability are officially registered and fulfill important preconditions for participation in public R&D programmes. Additionally, we incoporate a variable which accounts for firms' different human capital: *GRAD* is measured as the share of employees with university degree or technical college degree. We expect that firms with a larger basis of human capital are more succesful in undertaking innovation projects and thus also have a better access to governmental resources. Descriptive Statistics of all variables used are printed in Table 1.

4.3 Empirical results

4.3.1 Sustainability of public R&D funding

First we estimate the effect of former public R&D funding on companies‘ innovation activities. Table 2 presents the OLS results of four different empirical models. The first column shows the impact of former public funding *PFInt* on today’s innovation intensity *InnoInt*. The second column is a slightly modified model. There we use an additional lag of funding intensity, i.e. the time period of subsidisation is measured from seven to two years

[3] NACE is the European standard sectoral industry classification.

ago, because we have no information when a firm utilises its results of publicly funded research activities. The variation of the model gives an idea of the effect of public grants on innovation activities over time. Moreover, columns (3) and (4) deal with a further modification. The dependent variable is specified as given in equation (3) because this construction takes account of contemporary public fundings. *NetInnoInt* reveals the privately funded net activities without today's subsidies.

Table 1: Descriptive Statistics (2,451 observations)

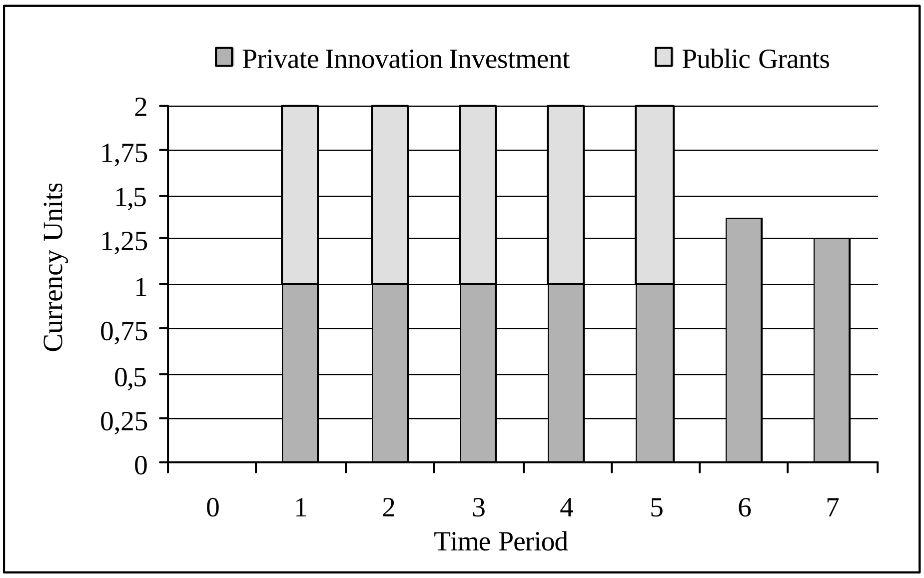
Variable	Mean	Std. dev.	Min.	Max.
InnoInt	8.18	13.83	.01	100
NetInnoInt	8.14	13.80	.01	100
PFInt	.06	.63	0	11
LPFInt	.06	.91	0	27.18
EAST	.37	.48	0	1
1/AGE	.12	.11	.005	1
EXPORT	3.68	11.66	0	100
DIV	.65	.21	.25	1
LFD	.88	.32	0	1
GRFF	.01	.12	-.37	.74
EMP	.65	9.39	.005	300
GRAD	28.23	28.54	0	100

All estimated coefficients of public funding are positively significant on the 5% level. Thus, the public R&D funding has a sustainable effect on private investment in innovation activities. The estimated coefficients of public R&D subsidies of the models in columns (3) and (4) are a little smaller than those of columns (1) and (2) but also significant on the 5% level. These findings point to the conclusion that firms try to transfer their publicly funded research results into innovations to realise a competitive advantage at the market.

Based on the estimated coefficients of columns (3) and (4), we illustrate a stylized firm behaviour. Figure 1 shows the annual expenditures of a service firm. To be in line with our empirical approch, we define *t* as a five year period. Suppose in a former period 0 the firm neither received public funding nor did it innovate. In periods 1 to 5 the firm receives one unit of public R&D funding. In our empirical model this means for a five year lasting research project, the firm receives one unit of public R&D funding per year. Due to the conditions in policy schemes, authorities finance a maximum of 50 % of total R&D project costs.[4] Thus, its innovation expenditure has to be at least two units in these years. Note, that we do not observe the expenditure in periods 0 to 5 in our regression model. In period 6 we estimated the net effect of 1.37 units of innovation expenditure due to one unit public funding in the former period. In period 7 the effect decreases to 1.26 (cf. Table 2, column 4).

[4] In projects of applied research, government tends to subsidise less than 50% of total R&D costs.

Figure 1: Estimated Effect of public R&D funding on Innovation Expenditures



The other results are interesting as well: The sectoral dynamics *GRFF* are an important reason for innovative activities. A shift in firm foundations induces higher innovation expenditures, i.e. a growing competition forces existing firms to develop new products or processes. On one hand processes may reduce costs for providing services. On the other, product innovations are supposed to create superior services which lead to advantages in competition. This points to the theory of product differentiation like Chamberlin's (1933) monopolistic competition.

Furthermore, studies assume that young firms need to have more innovative activities than established companies because of market entry barriers. To overcome disadvantages e.g. in market awareness, young firms might invest more in innovative activities than older ones. We confirm this hypothesis of innovative start-ups in the service sector, finding that *1/AGE* is positively significant.

Table 2: OLS regressions on innovation intensity

Exogeneous Variables:	Dependent variable: *InnoInt* (1)	*InnoInt* (2)	*NetInnoInt* (3)	*NetInnoInt* (4)
PFInt	1.73 ** (2.51)		1.37 ** (2.08)	
PFInt (lagged)		1.47 ** (2.23)		1.26 ** (2.00)
EMP	-.07 (-1.33)	-.08 (-1.33)	-.08 (-1.33)	-.07 (-1.33)
EMP^2	.00003 (.13)	.00003 (.12)	.00003 (.13)	.00003 (.13)
EAST	1.22 (1.59)	1.29 (1.68)	1.15 (1.51)	1.19 (1.60)
1/AGE	15.06 *** (3.53)	15.02 *** (3.52)	15.05 *** (3.53)	15.03 *** (3.52)
EXPORT	.02 (.66)	.02 (.66)	.02 (.64)	.02 (.65)
DIV	2.12 (1.58)	2.10 (1.60)	2.13 (1.60)	2.11 (1.58)
GRFF	9.51 *** (3.00)	9.70 *** (3.00)	9.37 *** (2.92)	9.48 *** (2.94)
Constant term	1.86 (1.50)	1.83 (1.47)	1.86 (1.50)	1.84 (1.48)
Industry Dummies (Reference class: Other Services)				
- Trade	-1.41 ** (-2.23)	-1.37 ** (-2.18)	-1.42 ** (-2.27)	-1.40 ** (-2.21)
- Transport	4.59 *** (5.44)	4.62 *** (5.47)	4.58 *** (5.43)	4.61 *** (5.46)
- Computer and Telecom Services	6.79 *** (7.53)	6.88 *** (7.63)	6.73 *** (7.47)	6.78 *** (7.55)
- Technical Services	6.29 *** (6.04)	6.33 *** (6.07)	6.30 *** (6.05)	6.33 *** (6.07)
- Consultancy	1.51 ** (2.19)	1.54 ** (2.23)	1.49 ** (2.16)	1.52 ** (2.20)
Test on joint significance of EMP and $EMP^2 \sim F(2,2433)$	13,54 ***	13,58 ***	13,46 ***	13,49 ***
R-squared	.09	.09	.09	.09

Notes: The t-values are printed in parentheses. All estimations include four time dummies. The estimates are not presented but they are jointly significant on the 5% level. The significance levels are indicated as *** = 1%, ** = 5% and * = 10%.

As usual, size is an important control variable. While the t-tests in Table 2 do not indicate any impact, a joint hypothesis test reports that *EMP* and EMP^2 are jointly significant. The relationship is nearly linear: Large companies invest relatively less in innovative activities than smaller ones. The industry dummies are also important and indicate large differences among sectors: The Computer and Telecom Services as well as the Technical Services sector show the highest innovation intensity.

The variable *EXPORT* has no effect on innovative activities. These findings are in common with a prior study for the German service sector by Ebling and Janz (1999). However, these results are in contrast to analyses for the manufacturing sector. For example, Antonelli (1989) finds a strong impact of exports on innovation activities of Italian firms. The variable *DIV* is insignificant in all estimations.

In conclusion, public R&D funding stimulates private investment in innovative activities. The subsidies even continue to have an influence on these investments in the future. However, the impact is decreasing with time. This leads us directly to the question of whether innovation activities enhance a firm's probabilitiy of being successful in applying for Federal Governments' R&D-grants in the future.

4.3.2 Determinants of future access to public R&D schemes

In the service sector there are still only a few firms which receive public R&D fundings: 67 firms in our sample have future access to R&D subsidies. All other firms are not funded. This implies a severe censoring of the dependent variable: 97 % of the observation are left censored at zero.[5] Hence, for our second research question we estimate Tobit models. This technique takes the censorship of the dependent variable *LPFInt* into account (see equation 4). At first, we estimate homoscedastic models. Furthermore, we control for groupwise heteroscedasticity. We include five size dummies and *EAST* in the heteroscedasticity term. The heteroscedasticity function is modeled as suggested by Greene (1997: 968). As the likelihood ratio tests in Table 3 show, the hypothesis of homoscedasticity is rejected. Thus, we only discuss the results of our heteroscedastic models. Note that time dummies were never significant in any estimation and were thus dropped in the final specification.

We find a significantly positive relationship between innovation expenditure and the future access to public research programmes. Besides that the share of highly qualified personnel has a considerable impact on the dependent variable. Both measures indicate the absorptive capacity of firms. Firms which spend a large share of their returns into the development of new products and processes are more likely to achieve valuable research results and are thus the target group of governmental initiatives. Moreover, with a larger share of skilled employees, a firm will be more succesful in participation in public R&D schemes. We conclude that university graduates maintain higher technological skills and hence are able to develop sound concepts and sophisticated methods for future research.

Additionally we observe some impact of other control variables: The legal form dummy indicating limited liability is positively significant. This supports the hypothesis formulated above: firms which have a legal entity, i.e. they are registered offically, are more likely to participate in R&D schemes in the future. We interprete this circumstance as risk averse behaviour by policy decision makers, maybe based on legal regulations or federal acts. Firm size measured by the number of employees is positively related to acquiring public funds in the future. Larger firms often maintain R&D departments and are more experienced in meeting the requirements demanded by government.

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[5] We drop one 3 digit sector as no firms are observed which receive public grants in the future. Our sample reduces to 2,220 observations.

Table 3: Tobit estimations on future access to public R&D policy schemes

Exogeneous Variables:	Dependent variable: Two period lead of public funding intensity (*LPFInt*)			
	Tobit	Tobit with Heteroscedasticity	Tobit	Tobit with Heteroscedasticity
InnoInt	.04 * (1.79)	.06 *** (2.64)		
NetInnoInt			.03 (1.11)	.05 ** (2.08)
GRAD	.12 *** (4.94)	.11 *** (4.56)	.12 *** (4.98)	.11 *** (4.54)
EMP	.06 *** (3.33)	.05 *** (2.71)	.06 *** (3.28)	.05 *** (2.68)
EAST	2.49 *** (2.46)	-3.71 (-1.35)	2.56 ** (2.50)	-3.83 (-1.35)
1/AGE	-1.97 (-.51)	-4.12 (-.88)	-1.85 (-.47)	-4.04 (-.85)
LFD	6.80 *** (2.61)	6.28 ** (2.11)	6.84 *** (2.60)	6.31 ** (2.11)
DIV	-3.81 * (-1.73)	-4.48 ** (-1.98)	-3.72 ** (-1.68)	-4.32 ** (-1.91)
EXPORT	.04 (1.57)	.04 (1.50)	.04 (1.54)	.04 (1.48)
GRFF	2.51 (.77)	1.74 (.49)	2.80 (.85)	2.01 (.57)
Constant term	-22.92 *** (-5.98)	-18.50 *** (-4.20)	-23.21 *** (-5.98)	-18.63 *** (-4.18)
Industry Dummies (Reference: Other Services)				
- Trade	.75 (.39)	-.07 (-.04)	.78 (.41)	-.09 (-.04)
- Transport	4.09 ** (2.55)	2.94 * (1.76)	4.22 *** (2.60)	3.00 * (1.78)
- Computer and Telecom Services	-2.28 (-1.19)	-2.24 (-1.18)	-2.18 (-1.13)	-2.13 (-1.13)
- Technical Services	-2-58 (-1.51)	-2.00 (-1.18)	-2.50 (-1.45)	-1.89 (-1.11)
- Consultancy	-2.75 (-1.45)	-2.62 (-1.39)	-2.79 (-1.45)	-2.66 (-1.41)
LR test on joint significance of size and *EAST* in the heteroscedasticity term ~ $\chi^2(5)$.	-	23.23 ***	-	22.65 ***
Log likelihood	-395.09	-383.48	-395.99	-384.66

Notes: The t-values are printed in parentheses. The heteroscedasticity term was modeled groupwise (see Greene 1997: 967). The heteroscedasticity term includes four size dummies (measured by number of employees) and *EAST*. The significance levels are indicated as *** = 1%, ** = 5% and * = 10%.

A larger product diversity (*DIV*) has a weak positive effect. In line with recent literature, we assume economies of scope in R&D and consider that research output is typically composed of inventions and discoveries in unexpected areas (Holemans and Sleuwaegen, 1988). Moreover, innovations may lead to larger spillovers if a firm has many different customers. Thus, the more a company is diversified, the higher is the probability to participate in public R&D programmes.

The export ratio *EXPORT*, firms' age and the competition measured by *GRFF* seem to have no impact on future access to public R&D schemes.

5 Conclusions

In this paper, we investigated the relationship between public R&D grants and innovative activites of German service firms in the 1990s. We come to the following conclusions: public R&D funding is complementary to private investment in innovation activities. The public grants have a sustainable effect on innovation expenditure: One Deutsche Mark (DM) of public R&D subsidies induces privately funded investment of 1.37 DM in the following time period. However, this effect is decreasing with time. If the public funding took place two periods ago, the privately funded investment is 1.26 DM.

We find evidence that innovation activities enhance companies' success in applying for public R&D grants in the future. This confirms policy makers' intention to prioritise innovative firms, because these companies have experience in R&D and already maintain resources such as scientists and laboratory equipment. With additional public grants, this may be used more productivly to achieve social needs.

Due to the the growing importance of the service sector in industrialized countries it is crucial to transfer the research work concerning the manufacturing sector to services. Our study is the first empirical approach evaluating public R&D policy schemes regarding companies engaged in the German service sector. However, further research is necessary: Attention has to be paid to the simultaneity between public funding and innovation expenditure. Moreover, it should be investigated, whether the supposed positive externalities attributed to R&D by manufacturing firms are also true for service innovations.

Appendix

Table 4: Service sectors included in the Mannheim Innovation Panel

WZ 93	Description
50	Sale, maintenance and repair of motor vehicles and motorcycles; retail sale of automotive fuel
51	Wholesale trade and commission trade, except for motor vehicles and motorcycles
52	Retail trade, except for motor vehicles and motorcycles: repair of personal and household goods
60	Land transport; transport via pipelines
61	Water transport
62	Air transport
63	Supporting and auxiliary transport activities; activities of travel agencies
64	Post and telecommunications:
64.1	Post and courier activities
64.2	Telecommunications
65	Financial intermediation, except for insurance and pension funding
66	Insurance and pension funding, except for compulsory social security
67	Activities auxiliary to financial intermediation
70	Real estate activities
71	Renting of machinery and equipment without operator and of personal and household goods
72	Computer and related activities
73	Research and development
74	Other business activities:
74.1	Legal, accounting, book-keeping and auditing activities; tax consultancy; market research and public opinion polling; business and management consultancy; holdings
74.2	Architectural and engineering activities and related technical consultancy
74.3	Technical testing and analysis
74.4	Advertising
74.5	Labour recruitment and provision of personnel
74.6	Investigation and security activities
74.7	Industrial cleaning
74.8	Miscellaneous business activities n.e.c.
90	Sewage and refuse disposal, sanitation and similar activities

Table 5: Industries used and regression aggregates

Industries	Aggregate
501	Trade
514	Trade
515	Trade
602	Transport
612	Transport
631	Transport
634	Transport
641	Transport
642	Computer and Telecom Services
702	Other Services
721	Computer and Telecom Services
722	Computer and Telecom Services
723	Computer and Telecom Services
726	Computer and Telecom Services
731	Technical Services
741	Consultancy and Advertising
742	Technical Services
743	Technical Services
744	Consultancy and Advertising
745	Other Services
748	Other Services
900	Other Services

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